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Experiments with ostriches -

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Reprinted from the Agricultural Journal of October, 1909.

CAPE TOWN :
CAPE TIMES LIMITED, GOVERNMENT PRINTERS.
Sm 1909.

EXPERIMENTS WITH OSTRICHES—X.

HOW THE BARS IN OSTRICH FEATHERS ARE PRODUCED.

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The experiments in connection with the investigations of the bars in ostrich feathers have progressed so far that a definite understanding has been reached as to how the defects are produced; on the other hand the endeavours to work out a remedy for their prevention have made considerable progress, but are not yet concluded. The following account of how the bars are formed will assist in an understanding of some of the difficulties involved in their prevention, and may direct attention towards a solution.

It is suggested, for reasons which will be evident later, that the name *shrinkage bar* should be applied to the ordinary kind of bar with which all ostrich farmers are familiar. It will serve to distinguish it from others known as *poverty bars*, *constriction bars*, and *vertical bars*, the formation of which will be described on another occasion.

Shrinkage bars are by far the most familiar and the most important of all the structural defects of the ostrich feather. It is rarely, if ever, that the plumage of a bird is altogether free from them, and when present in any number they lead to a serious depreciation in the value of the plumes, since they represent so many faults and weaknesses in the continuity of the flue. They are found on ostriches of all ages, though perhaps more frequently in chicks and young birds; moreover, they occur on the plumes of the wild ostrich as well as on those of the domesticated bird, and similar imperfections are occasionally to be seen on the feathers of all other kinds of birds.

Such a wide distribution as the above indicates that the barring defects are to be associated with something fundamental in the formation of feathers generally, not anything peculiar to the ostrich. It will be shown that their immediate formation, at any rate in the ostrich, is due to the shrinkage of the plastic feather-sheath around the soft and growing parts of the feather; and also that the shrinkage invariably takes place at certain well-defined places, which represent the weaker growth at night, resulting from a diminished physiological vigour. Produced in this way they may reasonably be expected to occur in all birds, since the feathers of all are formed alike.

The appearance of a shrinkage bar is but too familiar to anyone interested in ostriches or ostrich plumes (Fig. 1). It consists of a break or fault in the regular formation of the flue, a narrow interruption extending in an oblique manner across the feather, but not often passing all the way along both sides; the outer side of the shaft also may be notched at the same level. Looked at carefully a single bar is seen to represent a defect at practically the same place on each barb, and the actual defect

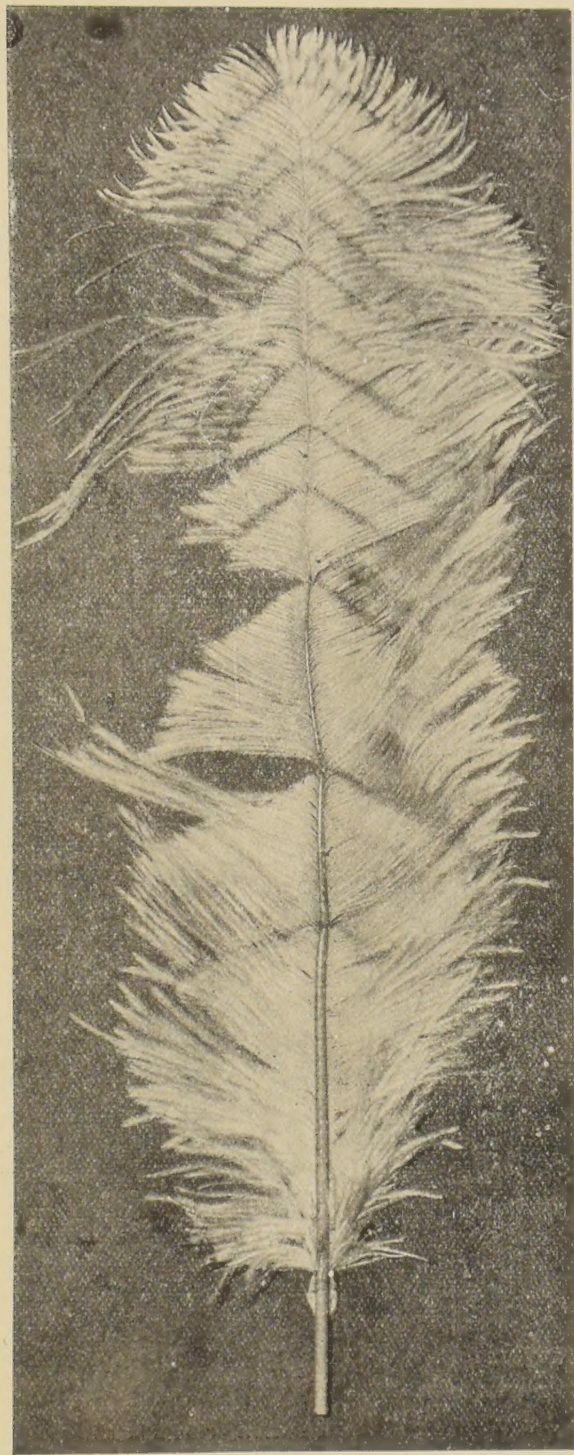


FIG. 1.

Plume showing very conspicuous bars at wide intervals apart, but closer towards the upper end. The flue is broken in places, corresponding with the bars. The shaft is also deeply notched at the bars, and towards the lower part shows the daily rings very clearly, though too faintly to appear in the photograph.

consists of an imperfect or deficient development of the barbules; also any single barb may have one or several defective places in it, depending upon the closeness of the bars to one another.

As shown in the sketch (Fig. 2), the barbules in the region of the defects are shorter and do not project from the barb to the same degree as elsewhere. In strongly marked examples even the barbs are not separated from one another, and the barbules are altogether absent, as in Fig. 3.

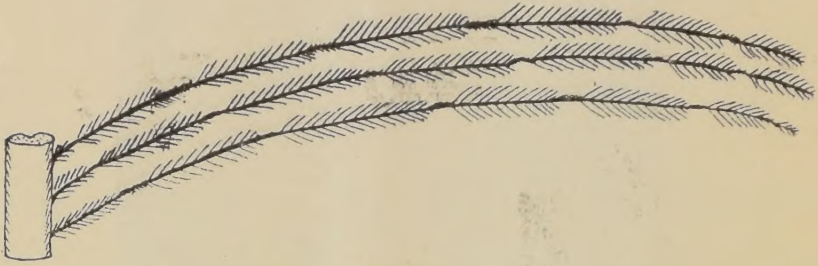


FIG. 2.

A portion of the shaft of a feather with three barbs attached to one side, each barb showing six barring intervals which correspond with the same number of complete bars on the entire plume. Where each bar occurs the barbules are either altogether absent or only partly developed, and the barb itself may be slightly kinked.

In addition, the barbs themselves are usually slightly bent or kinked, and if the fault extend across the shaft, the latter is deeply indented in an angular manner. *The entire appearance suggests that at the bar the feather has been subjected to a compression or shrinkage while it was still soft and in process of development, the pressure preventing the proper formation of the flue and shaft, and later their proper unfolding as the feather ripened.*

It is also of some importance to note that the vertical height of the individual bar varies but little; and further they are never broad, but always very narrow, rarely exceeding a sixteenth of an inch across. The reason for this will appear later.

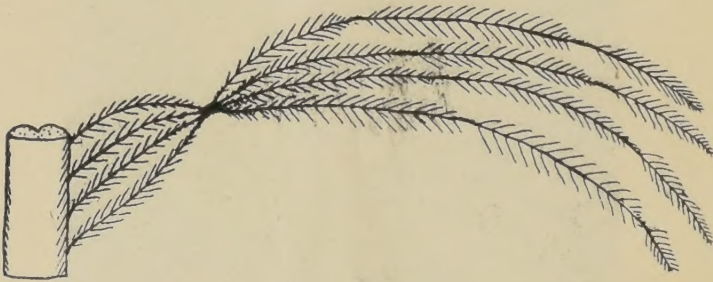


FIG. 3.

A portion of the shaft of a feather with four barbs attached to one side. The barbs are bound to one another where the deep bar occurs. On each barb two other barring places are shown beyond that at which they are united.

That the bar is a place of weakness in the flue is seen by the readiness with which breakages take place wherever the bars occur, when if numerous the breakages render the feather almost valueless. (Figs. 1, 4, and 5.)

The number of bars on different plumes varies. Sometimes only a few will be present, and then more especially towards the free end, while at other times they occur at more or less regular intervals along nearly the entire feather. On some plumes they are so arranged as to suggest an alternating regularity, that is, an arrangement at equal distances apart.

This can, however, be departed from in every respect, and often the bars show a most haphazard character in the number and extent of their formation. Sometimes they extend entirely across the plume, involving also the shaft in the middle, while again they may pass only part way across the flue, or may be practically limited to one side; further,

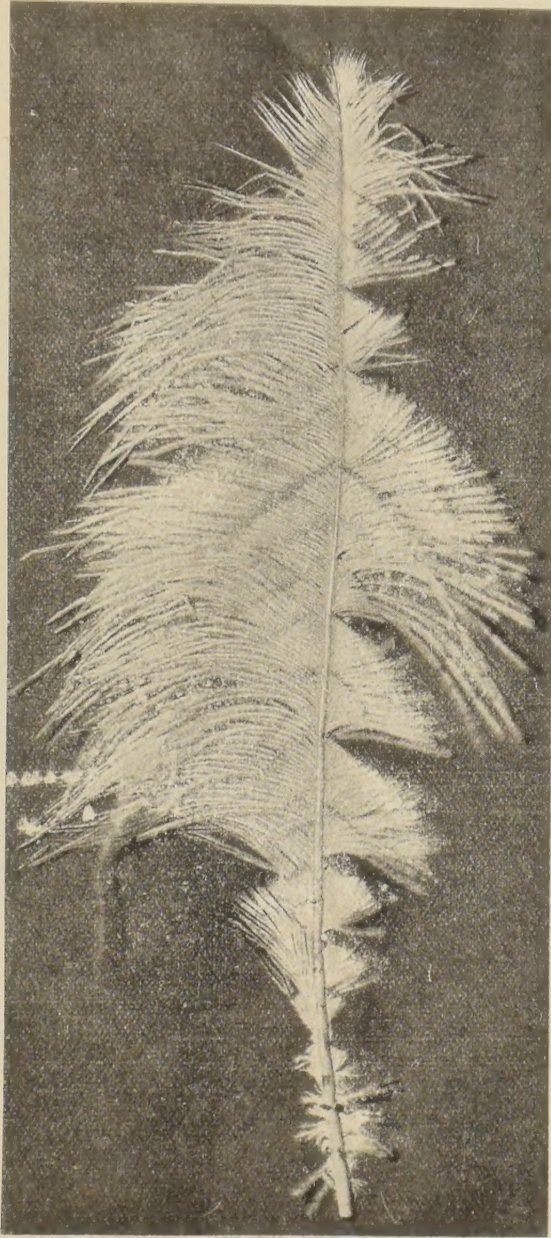


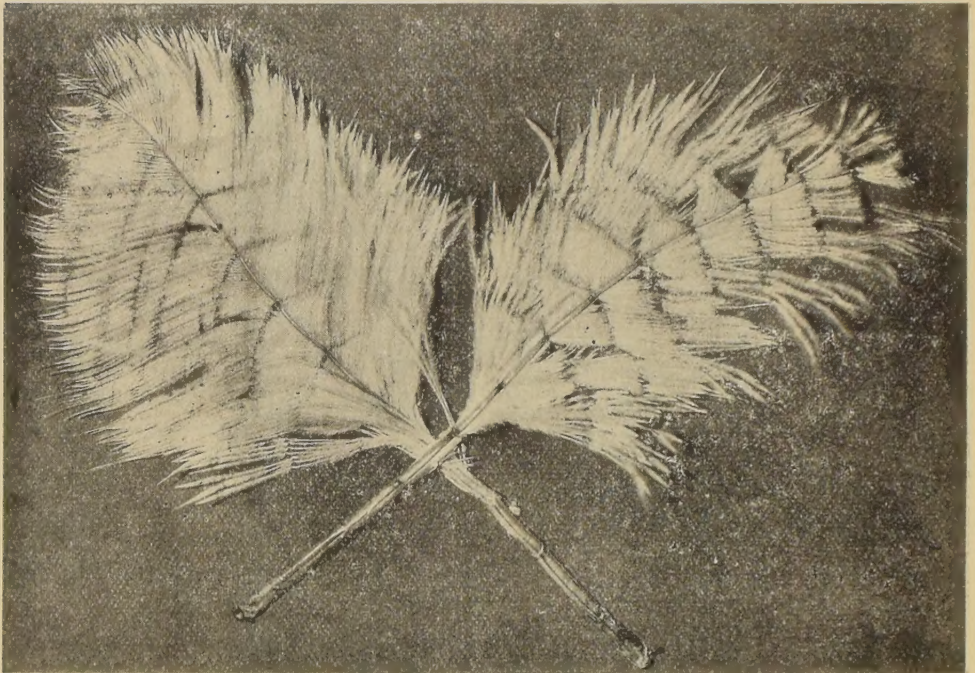
FIG. 4.

A strongly barred plume showing breakages of the flue where the bars occur.

although always narrow, the individual bar may be strongly or faintly indicated, and all stages occur between the extremes.

As regards the separate feathers on an ostrich, these also vary greatly in the degree to which they are affected. Some birds will have almost the entire plumage barred, the wing feathers, tails, and body-feathers, while in others only a few plumes will show the imperfection.

All the feathers seem equally liable to the defects, though they are more conspicuous on the commercial wing and tail feathers than on the small body-feathers. The most remarkable feature, however, and the one most puzzling to account for, is the extent to which variation is shown among the feathers growing under the same conditions, not only of different birds, but even on the same bird. Single wing plumes may be altogether free from the defects, while others, and especially the feathers towards the free end of the wing, will be freely barred. Sometimes the feathers of one wing will be affected, while those of the others are free. It is also found that single feathers growing out of time, that is, not as part of a full crop, are much more likely to be deeply barred than those constituting part of a full clipping. This applies more especially to single feathers



FIGS. 5 AND 6.

Two partly grown plumes showing very conspicuous bars. In the unexpanded portion are shown the deep notches or wrinklins on the feather-sheath which by constricting the growing feather produce the bars. Such deep bars occur at intervals of four or five day growth, not at each night ring; smaller notches, not seen in the photograph, represent the daily rings.

which are started in advance of the full crop, than to odd feathers appearing after a crop has begun its growth. Lastly it is well recognised that the plumes of some strains of birds have a great tendency to faultiness, while those of others are nearly perfect; and also that at one time the entire clipping from a bird will be barred, while at another the crop will be free from them. It is these many differences in the occurrence of the bars which render a simple solution of the problem peculiarly difficult.

THE IMMEDIATE CAUSE OF THE BARS.

The immediate cause of the bar is not far to seek. If one examines the lower unopened part of a growing feather in which the faults occur, it will be seen that the outer sheath is more or less deeply wrinkled or notched at intervals, and by stripping away the sheath it is found that

the developing feather inside is also indented. The indentations are seen to have in some way interfered with the proper formation of the feather beneath them; and from the appearances it can be understood that as the feather matures and comes to unfold a defect will be formed at the level represented by each wrinkling. This is well shown in Figs. 5 and 6, where the wrinklings on the unopened part of the feather clearly correspond with the barring above. From long observation every farmer knows, even before the plumes unfold, that bars will be present wherever the outer sheath is indented, while if the sheath is smooth all the way the feathers will be faultless. *It can be accepted, then, without any question, that the bars represent places at which the feather, while soft and growing, has been wrinkled or indented in such a manner as to prevent the parts beneath being fully developed.*

DAY AND NIGHT GROWTH.

The important point, however, is to account for the wrinklings which produce the bars, and to explain how they are formed. In some of the best examples of barring the defects occur at such regular intervals as to suggest that they correspond with some structural feature in the formation of the feather. And it has recently been shown that such is actually the case. *It is now known that feathers, even under the best of conditions, do not grow in a continuous manner, uninterruptedly from one end to the other, but consist of alternations of day and night growths, and that these alternations represent a daily increase and decrease in the physiological vigour of the bird.** Under ordinary circumstances, however, there is so little distinction between the night and day growth that as the feather ripens and opens out practically no evidence of it is seen, and the plume appears as a continuous formation without any interruptions; but under other circumstances the difference between the night and day growths becomes conspicuous and traces of it are noticed when the plumes expand, while in extreme cases the night growth becomes indicated by the wrinklings which result in the bar.

This new conception of the formation of a feather calls for careful consideration by ostrich farmers, and the evidence for it can be easily observed by themselves. If the wing be uplifted the alternations of growth can be seen on the unopened part of most growing feathers as a succession of narrow and broad rings which represent a difference in the feather density. The rings occur even where no bars are being produced. They are most pronounced in young blacks and drabs, in the portion of the growing feather freshly drawn from the socket and for some distance in the unopened part beyond the socket. This is owing to the fact that in blacks and drabs the dark unopened plume inside contrasts strongly with the translucent feather-sheath, and thus the denser and lighter parts are revealed. The soft growing part of a white wing plume is also often dark in colour, and in these the rings are easily distinguished where at all well formed. The denser broader rings represent the amount of growth added to the feather during the day, and the thinner, narrower rings the night growth, the alternation becoming evident owing to the fact that one part is denser or stronger than the other. The night growth appears as little more than a narrow ring of separation between the successive day growths, and it is manifest that the daily rate of growth can be ascertained by measuring the distance between successive day rings on the unexpanded feather. This is usually about a quarter of an inch in the wing plumes, but less in the others.

*This conception of day and night growth in feathers was first elaborated by Dr. O. Riddle of the University of Chicago (Biol. Bull., Vol. XIV., May, 1908).

As the various parts of the feather ripen and open out, the difference between the day and night growth largely disappears, even where conspicuous in the early stages of the unopened feather. A plume can be considered as perfectly formed only when this is the case, and ripe well-grown feathers often show no trace of the daily alternation. Most plumes, however, when held in certain positions reveal indistinct interruptions or weaknesses in the flue corresponding with those in the unopened feather, and sometimes the shaft is more or less indented on the outer surface, the rings becoming complete on the quill. These shaft indentations can easily be felt by passing the finger up and down the stem. In the best examples it will be found that the weakenings in the flue and also the indentations in the shaft occur at intervals of about a quarter of an inch, which, as stated above, is the rate of daily growth of the wing feathers. After one has become acquainted with the appearance of the day and night intervals, on both the growing and expanded parts of the feather, traces of them can be recognized on almost every feather, both on the flue and on the stem; they are not sufficiently strong, however, to be represented in photographic reproductions.

HOW THE DAY AND NIGHT RINGS ARE PRODUCED.

The further question presents itself: how is the alternation of day and night growth produced, and what is its influence on the feather? Without entering into details it may be stated that it has been proved experimentally that in most birds the temperature of the body is lowered at night and along with it the blood-pressure. This signifies that less physiological activity is taking place during the night than during the day, and consequently less feather material is then being formed; the feather continues to grow both day and night, but less vigorously during the night repose. The diminished activity in feather-growth at night particularly affects the barbules and the outside sheath, on account of their cells being furthest from the blood supply in the middle of the feather; the nutritive fluids do not ooze to their cells as freely as they do under the stronger pressure of the day. Hence these parts are the first to suffer in any lowered vitality. Though the shaft and barbs may grow uniformly day and night the barbules and sheath yet suffer from the diminished blood supply at night. From the above it follows that the night growth, if only for a few hours, is normally not as strong as that during the day, and therefore we get the alternation of the narrow and broad rings seen on the unexpanded feather.

Owing to their less density it is clear that the night rings will represent so many places of weakness in the feather, both as regards the sheath and the internal feather-forming material. With a bird in a high nutritive condition, and under ordinary conditions of day and night, the difference in the two growths is, however, barely perceptible; and even where it can be distinguished on the unopened feather it is scarcely noticeable when the plume matures and unfolds. Under other circumstances, particularly those of impaired or deficient nutrition, it has been proved that the difference between the two growths becomes intensified, and then the rings on the unopened feather remain as bands of different density on the expanded flue.

WRINKLINGS PRODUCED AT NIGHT RINGS.

Having now shown how the night rings are places of weakness in the growing parts of the feather the next step is to establish the connection between them and the wrinklings, the latter being always present when barring is at all conspicuous. If within the soft growing feather the

pressure of the blood be largely diminished, as would happen by having some of the blood withdrawn from the middle, the outside sheath of the feather will naturally tend to shrink or partly collapse, in order to accommodate itself to the diminished turgidity; and the manner in which this shrinkage takes place is the all important matter. *It is found that the feather-sheath always gives way at the weaker night rings, and in such a manner as to produce a narrow wrinkle, and the wrinkling naturally presses upon the soft growing plume below it and thereby interferes with its proper growth.* The blood-pressure within the growing feather has been diminished, and the wrinkling of the feather represents the mechanical effort of the more resistant outer part to adapt itself thereto.

The wrinkling must necessarily occur before the feather has become hard and firm, that is, in the early stage of its growth, while still soft and unformed. Several wrinklins are often seen when a barring feather is drawn green from its socket, the upper ones being more strongly indent-

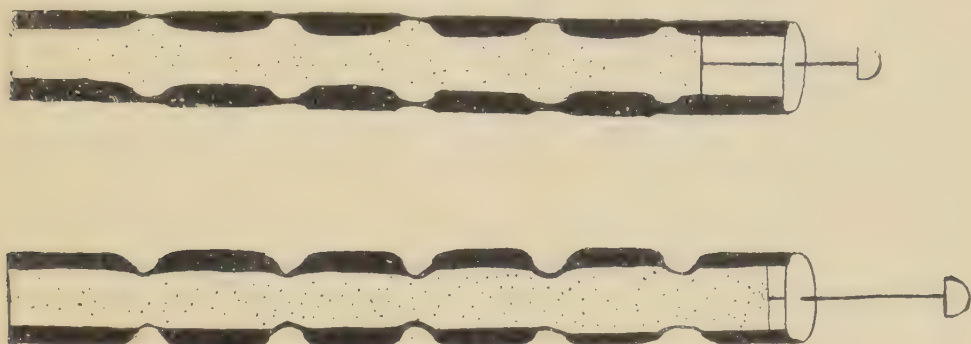


FIG. 7.

Model to illustrate how the feather becomes notched and indented at places corresponding with the weaker night growths when the internal blood pressure is reduced. The wall of the tube is made up of alternating stronger and weaker rings corresponding with the day and night growth. In the upper figure the internal and external pressures are the same, and tube remains smooth; in the lower figure the weaker parts of the tube have sunken in due to the diminished internal pressure produced by drawing out the piston.

ed than the lower. It is thus of some importance to find that the shrinkage bar commences at a very early stage within the socket, in fact as soon as the feather-sheath has become hornified, but while soft and plastic.

The wrinkling process may be illustrated as follows: a rubber tube closed at one end and fitted with a piston at the other is filled with water under ordinary pressure; if then the internal pressure is reduced, by drawing out the piston, the tube will partly collapse at the least resistant place, due to the outside pressure of the atmosphere upon the plastic rubber. The illustration more closely resembles what takes place in the feather if we suppose the rubber tube to be made up of alternate stronger and weaker rings. While under ordinary pressure the surface of the tube will be smooth, as in the upper diagram in fig. 7, but on reducing the internal pressure, by drawing out the piston, the tube will tend to collapse and wrinkle at the thinner, weaker rings, as shown in the lower diagram. And this is what happens in the growing feather, where the stronger and weaker rings correspond with the day and night growth.

We must look upon the growing feather as a long narrow tube, closed above and open to the blood supply below; also the tube is made up of alternate stronger and weaker rings, and is filled internally with the blood fluid under a certain pressure. The upper part of the tube where the

feather is nearly fully formed has become firm and resistant, while the lower growing part is still soft and plastic and capable of shrinking. Under these conditions any temporary lowering of the blood-pressure, as by partial withdrawal of the blood, will have to be met by the shrinkage of the wall of the tube, and this naturally takes place by wrinkling at the weakest places, the night rings within the socket. In the process of growth the lower parts of the tube, along with the wrinklings, passes higher and higher, and at the same time becomes more horny and resistant. Moreover, it would seem that the wrinklings once produced are never straightened out by any subsequent restoration of the pressure; indeed they become intensified as they grow upwards on account of the normal drying-up of the feather as the blood is withdrawn from the middle.

Good examples of the wrinklings on feathers are sometimes produced when a growing feather is drawn from the socket and then allowed to dry. The plucking of the unripe feather results in a loss of blood from the medulla, and the internal pressure being thereby diminished the sheath tends to shrivel upon the parts inside; the shrivelling takes place at the night rings, and the wrinklings assume the form of those produced naturally in barring feathers.

The deepest constrictions are rarely produced at each successive night ring, but, as shown in Figs. 5 and 6, may be about an inch apart, which represents four or five days' growth. Evidently a single collapse suffices to meet the variations of the blood pressure within this period, and there is no necessity for an indentation at each ring. By the time the feather at the wrinkling has grown an inch or so the sheath is becoming firm and resistant and not sufficiently plastic to continue to adapt itself to the pressure variations, and therefore a new collapse is formed lower down where the sheath is weakest.

HOW THE WRINKLINGS PRODUCE BARS.

With the above before us the production of a bar may be understood as follows. The wrinkling of the feather-sheath and the indentation of the feather substance below always occur while the feather is in unformed condition and within the socket. When this takes place the nutritive fluids in the region of the wrinklings will in some measure be squeezed away, and as a result of this and the compression the parts of the feather will not form properly, the barbs will be thinner and the barbules shorter, and a place of weakness and feather deficiency will result, to be revealed when the plume opens out. The deeper the wrinkle the greater is the compression, the less flue is formed beneath it, and the more conspicuous is the bar; so that all degrees in the production of a bar are represented, often on the same feather. Some are barely noticeable, while others are very evident; moreover any wrinkle rarely passes all round the growing feather, and in this we have the explanation of the fact that the bars do not often extend completely across the plume.

It has been supposed that the mere alternation of the day and night growth would suffice to produce conspicuous bars in birds, but so far as the ostrich is concerned, this is not the case. *It is only when the wrinkling takes place in addition to the weakened night growth that defects of importance appear; hence on the growing feather, even before the plume opens out, it is quite easy to see whether or not bars are forming.* It would be difficult to conceive that the difference between the nutrition of the growing feather during the day and the night could be so great that in one case the barbules would be fully formed while in the other they would be absent, whereas all the appearances can be satisfactorily explained by the production of the indentations from the partial collapse

of the feather-sheath. As the wrinklins are rarely produced uniformly they afford a satisfactory explanation of the variations in position and extent of development of the faults as compared with the regularity which would be expected from the day and night differences alone.

It results from the above that *two conditions are necessary for the production of shrinkage bars in ostrich feathers. First, the alternation of day and night growth, due to a slight difference of blood-pressure as the feather is forming, giving rings of different thickness or density; second, greater variations in the blood-pressure within the medulla of the feather, leading to a partial collapse or wrinkling of the feather-sheath at the weaker night rings, whereby the feather is prevented from attaining its full development at those particular places.*

The ordinary alternation of day and night growth alone sometimes gives a feeble indication of barring, but I doubt if it would ever be so serious as to call for the consideration of the practical farmer; when, however, it is supplemented by the wrinkling at the places of less density we have a combination of conditions capable of producing all the observed defects. The indentations stop the proper nutrition of the feather at that particular level, and thus greatly intensify the weakening of the growth from the lowered night pressure. The combination is one of reduced nutrition acting as a primary agent supplemented by a secondary mechanical effect, the wrinkling. Both may, and probably do, take place at one and the same time; but we may have the night ring without any bar. The factors which produce a night ring will give rise to a bar when continued far enough.

Evidently the variations in the blood-pressure and the responses to it vary greatly in individual feathers, even among those growing over the same part of the body, and it is this which accounts for the haphazard character of the appearance of the bars alluded to earlier. The variation is difficult to understand, but can be partly explained by the different stages of feather-growth represented at one and the same time in the plumage as a whole, and also by the differences in exposure of the individual feathers. Odd feathers are usually more exposed than those forming part of a full crop, and are always more likely to be barred. Sometimes where a number of feathers are all at the same stage of growth, as in the case of wing and tail feathers after artificial plucking, it is found that a bar will be formed at the same level in all the growing plumes, showing some marked physiological change in the bird as a whole. But usually the barring in individual feathers is quite independent, a fact which adds greatly to the difficulty of overcoming it.

The place of occurrence of the bars and their extent across the flue have also been stated to vary much in single plumes. In the shrinkage, consequent upon the reduction of pressure, it can easily be understood that the wrinklins are not always produced at exactly the same place round the weaker night rings, nor do they always assume exactly the same form and depth; sometimes one deep indentation will occur at a ring, while at others there may be several; some will be on one side of the feather, and some on the other; some partly encircling, others almost completely so. As a result the flue on opening out is differently affected at different levels.

WHY THE BARS ARE ALWAYS NARROW.

It has been stated that the shrinkage bars are always very narrow in their vertical extent, and this now admits of a simple explanation. They are the same vertical height as the night rings. The latter are always small compared with the day rings, as the feather grows but little during the few hours of the night, and it is only the narrow night part of the

growing feather which is indented to form the bar. A broad bar can never be produced even by continued shrinkage; all that happens in this case is that the sheath wrinkles more and more deeply upon the soft feather and interferes to a greater degree with the formation of the barbules and barbs, and even indents the shaft. The night rings are about a sixteenth of an inch in height, and this is usually the vertical extent of a bar.

PRODUCTION OF THE BARS SOLVED—THE PROBLEM AS TO THEIR PREVENTION.

While in the above account we may claim to have solved the problem as to how the bars in ostrich feathers are produced, there yet remains the greater question as to how their formation is to be prevented, which is really the practical issue with which the farmer is concerned. From what is established we can understand that *the object at which to aim in preventing the bars is to maintain the blood-pressure within the growing feather at as uniform a rate as possible during both day and night; uniformity of conditions during the feather growing period is the key to success in the elimination of the bars.* By maintaining this uniformity we may hope to minimise the difference in the feather growth during the day and night periods, and also give no opportunity for a mechanical collapse consequent upon a considerable reduction of pressure. Anyone acquainted with the physiology of animals will, however, realise the difficulty of maintaining practical uniformity of blood-pressure in organs which project so much beyond the general surface of the body as do the growing feathers of the ostrich, and which at the same time have such a rich supply of blood within them. The great difficulty is to overcome the variations in individual feathers, for usually it is not an interference with the growing feathers as a whole, but merely an example of the slight variation in blood-pressure to which any organ or part of an organ may be subject.

The relationship between blood-pressure and feather perfection in the ostrich appears to be of such a delicate nature that any slight disturbance is productive of faults. Indeed under ordinary farming conditions this delicacy of relationship is never quite maintained, and we rarely get a plume showing perfection of growth. We can, however, enquire as to the conditions under which it is least likely to be disturbed.

In the course of the experiments a great deal of evidence has been accumulated as to the conditions under which the blood-pressure varies, in other words as to the conditions under which bars are and are not produced. As would be expected, the conditions are very varied, but it can be accepted that they are largely, though not wholly, concerned with the nutritive condition of the bird. Something also seems to depend upon the exposure of the individual feather. For it has been seen that odd feathers growing out of time, and therefore not covered and protected by the others in a full crop, are very liable to be barred; also a slight variation in blood-pressure would have a greater proportional effect upon single feathers than upon the members of a full crop.

There is plenty of evidence which proves that with strong vigorous birds kept in a good condition of health, little trouble need be feared from the presence of bars, where a full crop is being produced. The maintenance of the proper nutritive state of the ostrich, however, involves a thorough practical experience of the bird under its various phases, and often individual birds are somewhat out of feather-growing condition when not suspected. What is called for is a strong supply of blood to maintain a constant and regular stream to all the growing feathers under the many variations to which the domesticated bird is subject; anything

which interferes with this is found to have an influence upon the regularity of the growth of the feather. Thus any of a great number of influences may be at work, either together or separately, tending to interfere with the well-being of the bird; and it follows that all the causes which have been assigned by the practical farmer as concerned in the production of bars probably have their justification to a greater or less extent. We need only mention: (a) insufficiency of suitable food, especially during droughts; (b) ailments and accidents of every kind; (c) exposure to inclement weather or to rapid changes of temperature; (d) the presence of internal and external parasites and the treatment against them; (e) weakening of the constitution by in-breeding; (f) lack of variety of food and place; and (g) rough handling during the operations of clipping and quilling. Anything in fact which interferes with the proper nutrition of the bird has been proved over and over again to influence the production of the faults. Beyond all these a great deal seems to depend upon the individual constitution of the bird, and even upon the individual feather. Often among birds in the same troop and apparently in equally good condition of health the feathers of some will be barring while others are perfect, and nearly always in a complete crop some plumes will be barred and others free.

Again seasonal changes have often a marked influence on the barring defects. The ostrich is undoubtedly in a more vigorous feather-producing condition at certain times of the year than at others. In the Eastern Province feathers grown during the dry winter months—May to August—are rarely as good and free from bars as those grown in the spring and summer months when green food is abundant.

The defects are just as frequent, if not more so, in superior feathers as in inferior plumes. One often sees high grade feathers deeply barred towards the tip while short, stalky plumes are uniformly grown. Indeed the short stiff feathers occasionally growing alongside high grade feathers are less likely to be barred than the latter. It may be held that the greater the blood supply in the medulla the more likely is the blood-pressure to undergo such changes as would result in the production of a bar.

IS THE OSTRICH MORE SUSCEPTIBLE TO BARRING THAN OTHER BIRDS.

It may be asked whether the ostrich is more susceptible to feather defects than other birds. It is now well established that bars may be found in a state of nature in the feathers of all kinds of birds, and can be produced artificially by subjecting them to adverse conditions, such as starvation, hence the term "poverty bar." It must be acknowledged, however, that in no bird do they appear to be formed so readily and so consistently as in the ostrich, for they are prevalent in the wild as well as in the domesticated state, and no plumage is ever wholly free from them. In certain other birds, however, I have found that at times the defects are just as plentiful as in the ostrich. Several Black Minorca fowls in my possession have the wing and tail quill-feathers quite as strongly and regularly barred, in proportion to the size of the feather, as in any ostrich plume. There is reason to suppose that in these particular fowls in-breeding has taken place to a considerable degree, and this may have reduced the constitutional vigour. Also in a South American ostrich, *Rhea americana*, in the Albany Museum, the entire plumage, including all the body feathers, is barred in a greater proportion than I have ever observed in the African ostrich.

From a general survey of the situation I am convinced that the production of a perfect plumage is a much more delicate matter in the ostrich than in birds generally. All the wild and domestic birds with

which we are familiar are probably subject to just as many vicissitudes as is the ostrich, and yet faulty feathers are the exception among them, whereas among ostriches their presence is the rule. Even when the utmost care is given to the birds by farmers with years of experience, and with all the best farming conditions available, the feathers are still more or less defective, while under adverse conditions they may be nearly worthless. It can safely be asserted that ostriches under ordinary farming conditions, even where kept in a good state of health, are incapable of producing a plumage entirely free from bar faults, and such would also appear to be the case with the wild bird, so that the trouble cannot be put down to domestication alone. *It is a remarkable biological fact to find that an animal is incapable, even under highly nourished conditions, of producing an important part of its structure in a wholly perfect manner.* Regarded from an evolutionary point of view we may surmise that the feathers of the ostrich, being of no use as organs of flight, are retrograding, that is, it has become of greater advantage for the bird that the nutritive forces should be turned in other directions; and, therefore, we get the very delicate balance of feather nutrition, to be disturbed by the slightest adverse conditions.

I am inclined to consider that climatic changes also have a greater influence upon the ostrich than upon other birds. Its plumage is apparently not well adapted for protecting the body from the great extremes of temperature to which it is subject. Considering the readiness with which the bird erects its feathers on warm days, it would seem that they are not very effectual as a protection against the sun's heat, and we may assume that the plumage is just as ineffectual in the retention of the body-heat during cold weather. Owing to the absence of hooklets on the bar-bules, the flue of the ostrich, like that of other running birds, is loose in character compared with the compact vane of flying birds; and it can hardly be considered that a loose plumage will serve to protect the body from temperature changes so effectively as an almost air-tight covering. It is significant in this connection that the *Rhea* referred to above as having an intensely barred plumage belongs, like the ostrich, to the flightless birds with loose flue to the feathers. The practical absence of down feathers and filo-plumes in the ostrich, compared with other birds, also needs to be taken into account. The smaller down feathers, which in most birds are interspersed among and below the larger contour feathers, form, as it were, a second plumage which serves for the better retention of the heat of the body; but the ostrich is without this additional protection, having only its single covering of contour feathers. Further, the ostrich has extensive naked areas altogether destitute of feathers, namely, the legs and a large space along each side of the body. Variations of temperature acting upon such an insufficiently protected skin would be extremely likely to modify the blood-pressure, both within the greatly protruding growing feathers and the surface of the skin itself. We need only mention the extreme changes in temperature between the day and night to which South Africa is subject, and even the remarkable changes often from day to day, to be impressed with the influence which temperature must exert upon the ostrich.

The great sensitiveness in the nutrition of the feather and the marked responsiveness to climatic changes will go hand in hand in producing those variations of blood-pressure within the growing feather which result in the formation of bars; either would be sufficient to produce the faults, but generally they will act conjointly.

One can readily understand that if the ostrich has this natural tendency to the production of faulty feathers, the tendency will be likely to be accentuated under domestication, particularly under the varying and often uncertain farming conditions which prevail in South Africa. The

change from the open wandering existence of the wild bird, free to choose a variety and abundance of food, to the restricted life in camps, often subject to irregularities and limitations in the food supply, can but emphasize any natural weakness towards a defective plumage. The practice of artificial plucking as compared with the natural moulting of the feathers may also be an important factor, though it must always be remembered that on chicks which have never been plucked barring is just as prevalent as on older birds.

If we agree that barring defects are much more prevalent in the plumage of the ostrich than of other birds, and are produced with such readiness, it is manifest that their total elimination under domestication will be a matter of considerable difficulty, and will call for a very thorough knowledge of the responses of the bird to all the varied treatment and conditions to which it is subject. We have, in fact, to counteract a natural tendency within an animal. It is, however, clearly recognised by ostrich breeders that some strains are far more subject to the faults than others, and great advances are now being made in the selection for breeding purposes of parents in which the tendency is least pronounced; also the highly nutritive condition in which superior birds are now maintained is doing much to counteract the evil, so that the solution of the problem of overcoming the tendency to faulty plumage is by no means without its hopefulness. *Farmers are certainly acting wisely in not breeding from birds which show a strong tendency to bars.*

When the farmer has done his utmost to maintain his birds in the best feather-producing condition, there still remains the question whether anything can be done to supplement his efforts, to give him assistance in his endeavours and to render his results more certain. It is towards this that the experiments have been directed for some time, and encouraging results are being obtained. The matter is one of such complexity as to involve a wide experience of ostrich management, and some time must elapse ere the results can be announced with that assurance necessary to warrant their recommendation to the practical farmer. Until under experimental conditions or actual farming practice it is possible wholly to eliminate the bars, it is manifest that the difficulty of analysing the separate barring factors and of providing against them is very great. Meanwhile something definite has been achieved in having settled where the trouble lies, and one can proceed with greater assurance and hopefulness in the endeavour to overcome the difficulties presented.

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